CS15210: Modes and Media

Helen Miles (hem23@aber.ac.uk)

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(based on slides by Mike Clarke)

Previously, in CS15210...

- ASCII, standard coding system using 7-bits for a character
- Parity: odd, even, vertical, horizontal
  - Vertical parity uses a single extra bit to help spot errors
  - Horizontal parity allows us to pinpoint the error
- Transmission
  - Modes: simplex, half-duplex, full-duplex
  - Types: parallel, serial synchronous, serial asynchronous

Contents

Transmission Medium

The transmission medium is the substance transporting the signal from one end of the communications channel to the other

i.e. types of cables, wireless, etc.

Factors Affecting Choice of Medium

- When selecting a transmission medium (i.e. different kinds of cables, satellite, radio, etc.), there are a few things to consider:
  - Cost of the medium
  - Channel capacity
    - How much data can you transmit?
    - Measured in Mbps (megabits per second)
  - Robustness
    - Does it need to be particularly resilient to interference?
  - Security
    - e.g. Wi-Fi is vulnerable

Channel Capacity ('speed')

The number of bits per second that can be transmitted over a communication channel

- It depends on:
  - the nature of the transmission medium, i.e. radio, cable, etc.
  - the transmission distance
  - the characteristics of the terminal equipment, i.e. what is at either end of the transmission?

Propagation Delay

The time required for a signal to get
from one end of a channel to another

Electrical signals travel along wires at about two thirds the speed of light in a vacuum, i.e. about $2 \times 10^8\,\mathrm{m\,s^{-1}}$

If we have a 2 km line, how long does it take?

$$time = \frac{distance}{speed}$$

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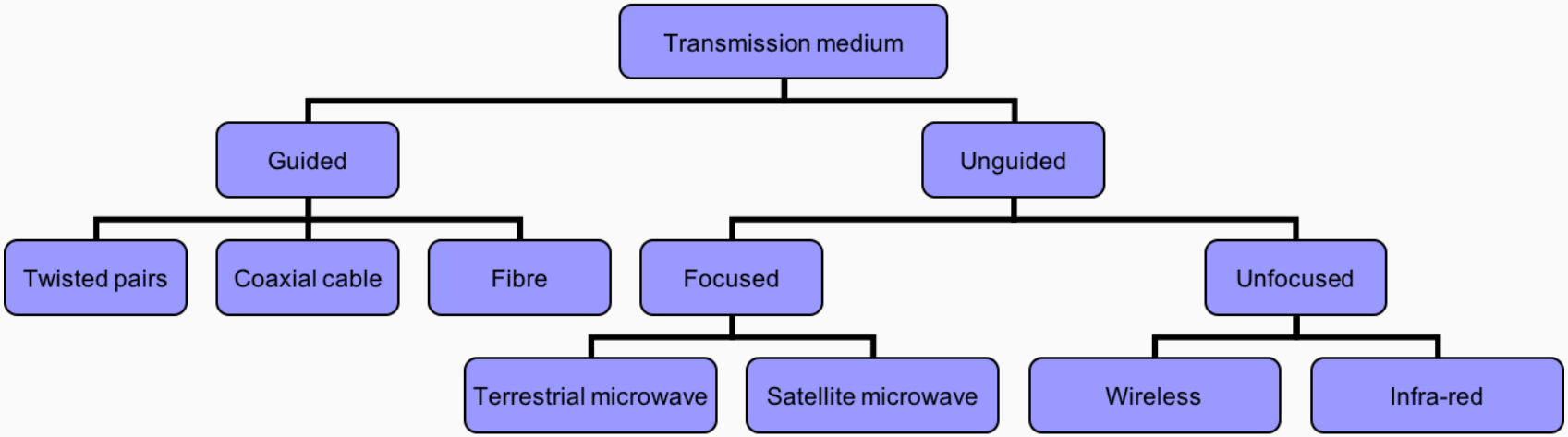
If we have a 2 km line, how long does it take?

$$time = \frac{2 \times 10^3}{2 \times 10^8} = 1 \times 10^{(3-8)}$$

$$time = 1 \times 10^{-5}\,\mathrm{s} = 0.000\,01\,\mathrm{s} = 10\,\mu\mathrm{s}$$

Types of Transmission Medium

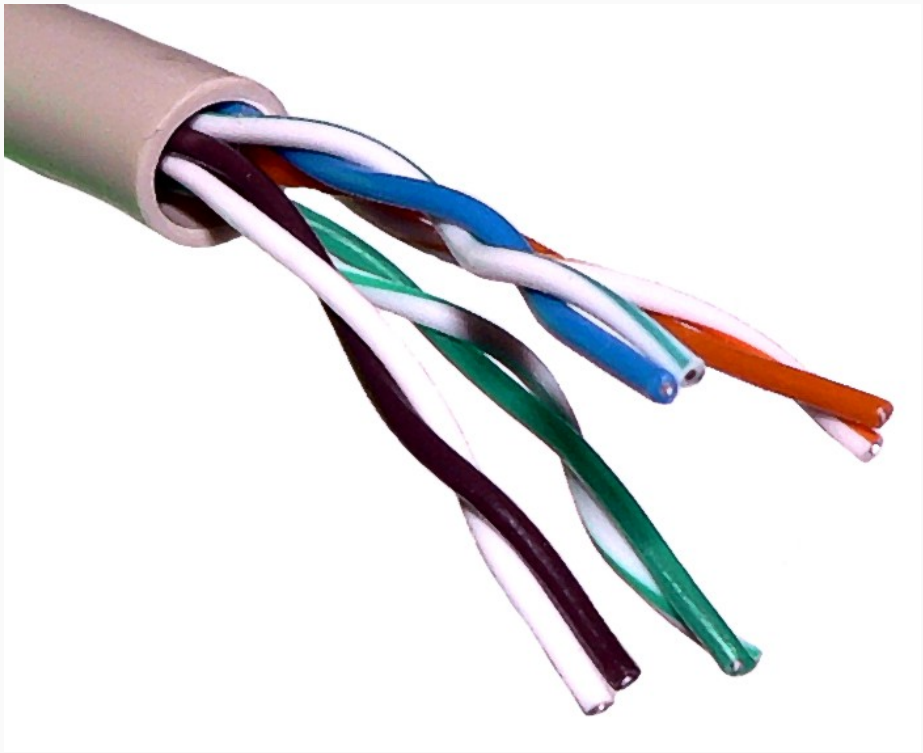


You might be asked what category a medium is in...

Types of Transmission Medium

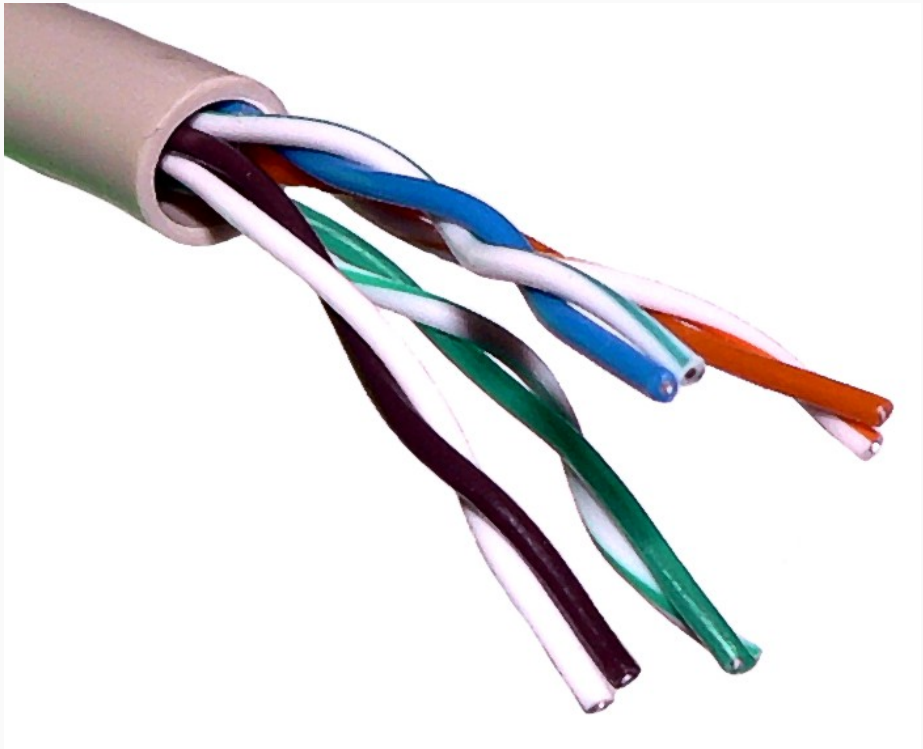
- Guided:
  1. Twisted pairs
  2. Coaxial cable
  3. Fibre
- Unguided
  - Focused:
    1. Terrestrial microwave
    2. Satellite microwave
  - Unfocused:
    1. Wireless
    2. Infrared

Twisted Pairs



A pair of insulated copper wires twisted round each other;
the twists reduce the effect of noise

Twisted Pairs



The wires are colour-coded to identify the pair number, sometimes with a tracer to help match pairs

Twisted Pairs

- UTP: Unshielded Twisted Pair
  - As in previous slide, no shielding of the wires
- STP: Shielded Twisted Pair
  - Wires are encased in metal foil or mesh to reduce interference
  - Different kinds:
    - Overall shielding
    - Individual pair shielding
    - Can also use both

Twisted Pairs Standards

- **Category 1** and **2** are basic, old-fashioned, only suitable for voice telephony and very low speed data transmission

- **Category 3** must have at least three twists per foot
  - suitable for speeds up to 10 Mbps
  - Now standard for most telephone systems

Twisted Pairs Standards

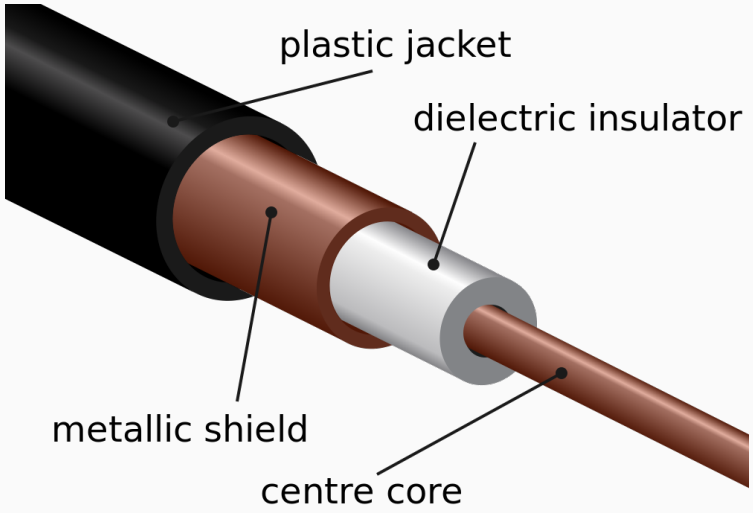
- **Category 5** and **5e** must have at least five twists per foot
  - suitable for data transmission up to 100 Mbps
  - **5e** has tighter specifications against crosstalk*
- **Category 6** must have at least six twists per foot
  - suitable for data transmission up to 1 Gbps

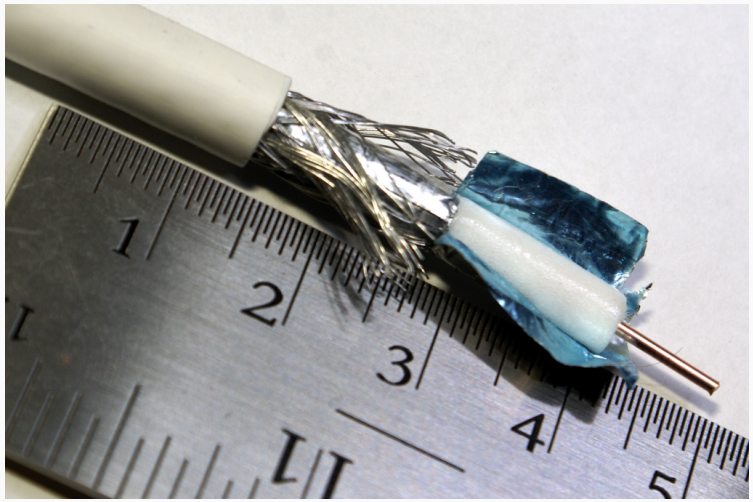
*Crosstalk: when one wire picks up the signal being transmitted on another

Properties of Twisted Pairs

- UTP is cheap and easy to install
- STP is more expensive than UTP but offers better resistance to noise, in particular to crosstalk
- Suffers from high attenuation so can only be used over short distances ($< 100\,\mathrm{m}$)
- Easy to tap, not very secure

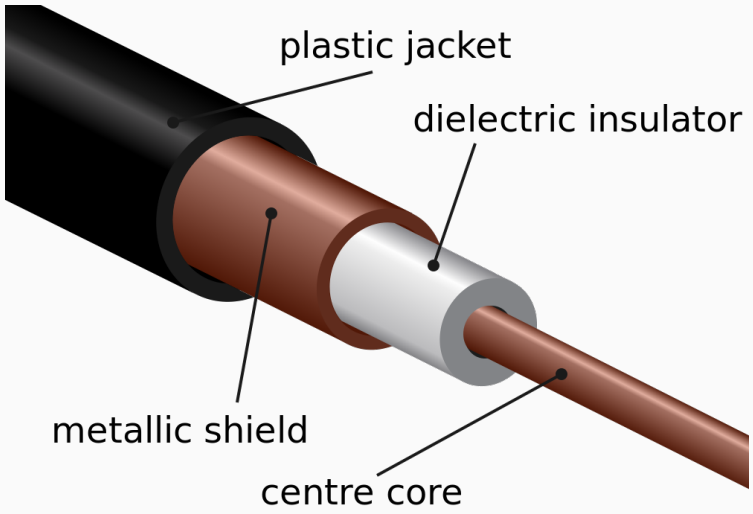
Coaxial Cable

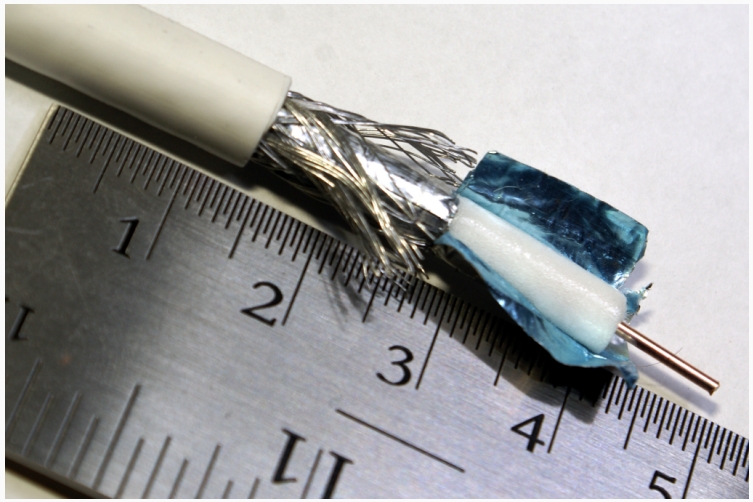




A copper wire surrounded by an insulator,
a metallic shield, and an outer plastic jacket

Coaxial Cable





The insulator is usually made of plastic,
and the metallic shield may be foil sheet and braiding

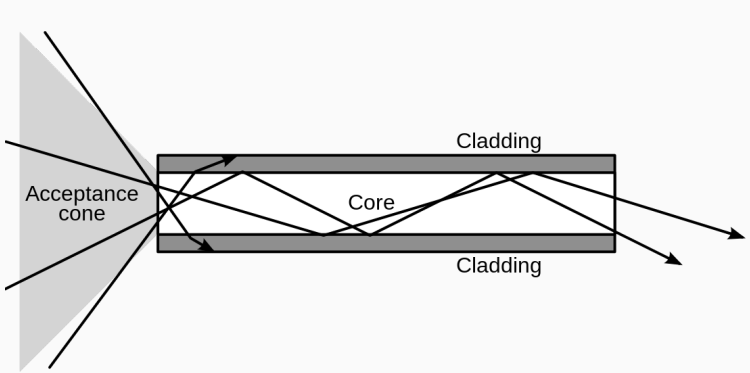
Properties of Coaxial Cables

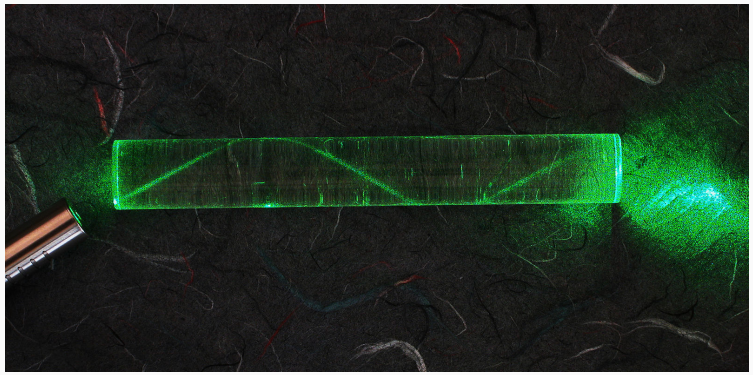
- Similar cost to STP
- Fast, 1 Mbps to 1 Gbps
- Moderate susceptibility to attenuation and noise, can be used over 1–2 km
- Easy to tap

Properties of Coaxial Cables

- There is a standard defining different grades of coax, e.g. RG-6, RG-7, ...
- The different standards state variance in
  - shield (number of layers)
  - thickness of the core and insulation layer
  - characteristic impedance of the wire (the ratio of the amplitudes of voltage and current)

Optical Fibre





A silica fibre surrounded by cladding and an outer jacket; light is reflected down the fibre core

Properties of Optical Fibre

- Uses light to carry the signal rather than electricity
- Much less susceptible to attenuation and interference
- Very high channel capacities are possible, $1.48\,\mathrm{Tbit\,s^{-1}}$ has been recorded by researchers[†]

[†]F. Poletti, et al. "Towards high-capacity fibre-optic communications at the speed of light in vacuum." Nature Photonics 7.4 (2013): 279-284.

Properties of Optical Fibre

- Difficult to tap
- Expensive, but getting cheaper
- Fragile and difficult to install
- Now forms the basis of most long distance voice telephony and data transmission; undersea fibre is used for inter-continental traffic

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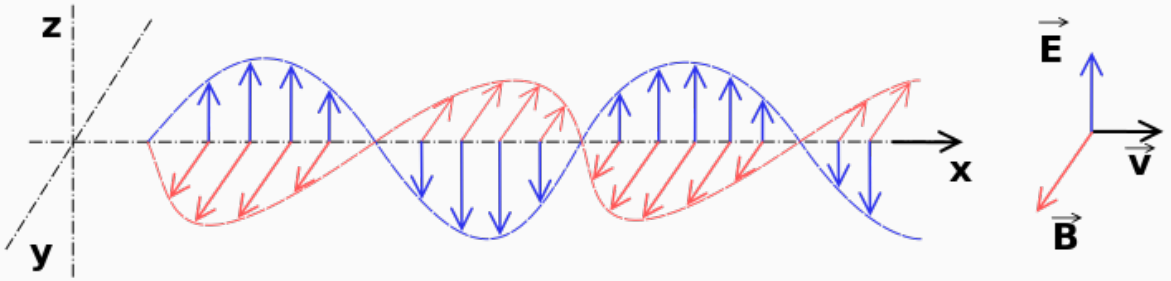
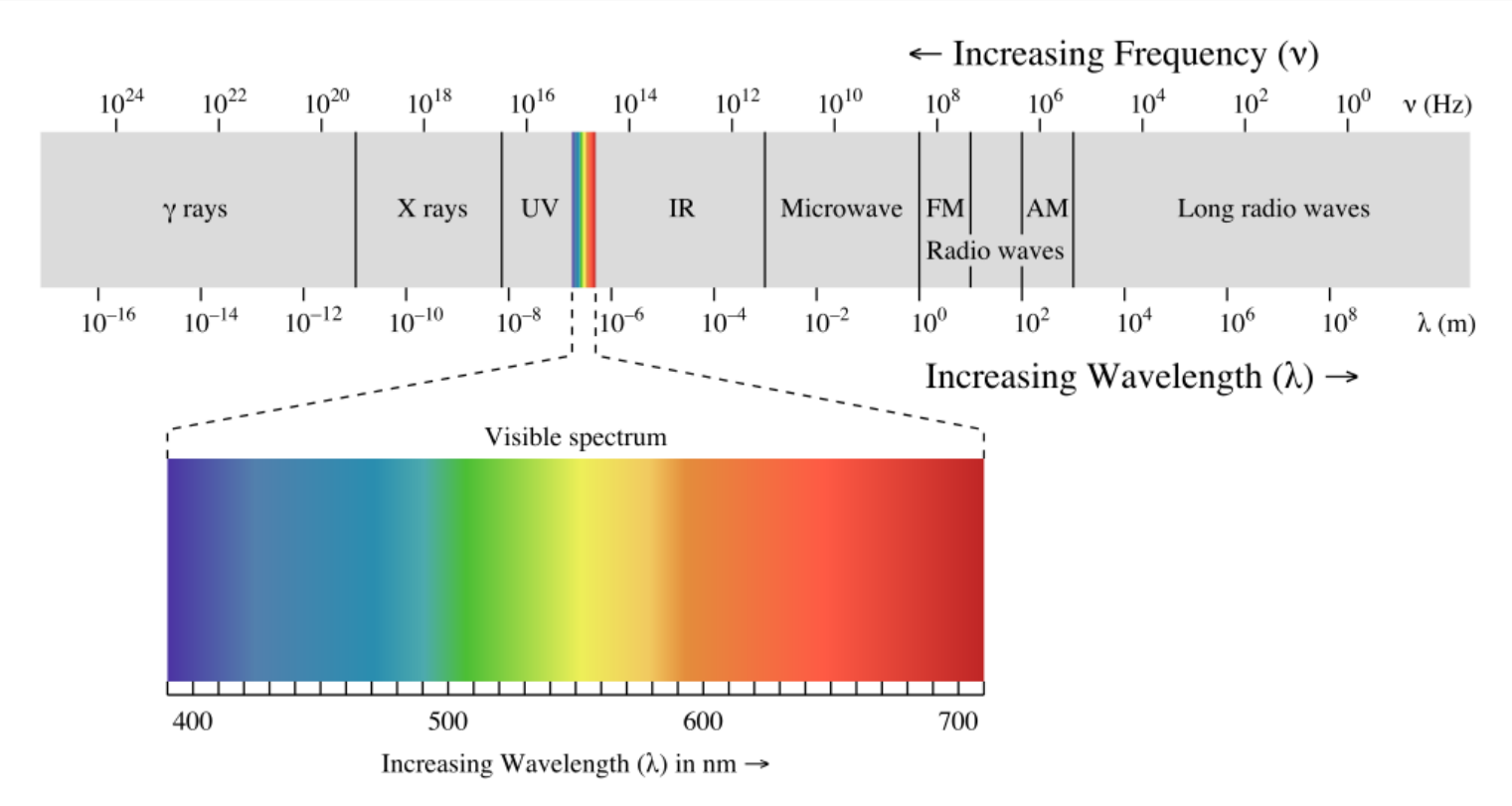
Electromagnetic Radiation



- All unguided transmission is based on the use of electromagnetic waves (radiation)
- 'Electromagnetic waves' includes radio waves, light, radiant heat, X-rays, and many other kinds of radiation
- The properties of electromagnetic waves depend on their frequency

The Electromagnetic Spectrum



The Electromagnetic Spectrum (Approx. Ranges)[‡]

long radio	$3\,\text{Hz}$ to $3 \times 10^3\,\text{Hz}$	$3\,\text{Hz} - 3\,\text{kHz}$
radio	$3 \times 10^3\,\text{Hz}$ to $3 \times 10^9\,\text{Hz}$	$3\,\text{kHz} - 3\,\text{GHz}$
microwaves	$3 \times 10^8\,\text{Hz}$ to $3 \times 10^{11}\,\text{Hz}$	$300\,\text{MHz} - 300\,\text{GHz}$
infrared	$3 \times 10^{11}\,\text{Hz}$ to $4 \times 10^{14}\,\text{Hz}$	$300\,\text{GHz} - 400\,\text{THz}$
visible light	$4 \times 10^{14}\,\text{Hz}$ to $7 \times 10^{14}\,\text{Hz}$	$400\,\text{THz} - 700\,\text{THz}$
ultra-violet	$3 \times 10^{14}\,\text{Hz}$ to $3 \times 10^{16}\,\text{Hz}$	$700\,\text{THz} - 30\,\text{PHz}$
X-rays	$3 \times 10^{16}\,\text{Hz}$ to $3 \times 10^{19}\,\text{Hz}$	$30\,\text{PHz} - 30\,\text{EHz}$
γ-rays	$3 \times 10^{19}\,\text{Hz}$ upwards	$30\,\text{EHz}+$

[‡] `http://missionscience.nasa.gov/ems/index.html`

Use of Frequencies

- Low frequencies, up to 300 kHz, are used for long range radio navigation, submarine communication and other specialised purposes
- LW radio starts around 150 kHz
- Frequencies between 300 kHz and 300 MHz are used for radio, VHF TV and aircraft communication

Use of Frequencies

- Frequencies between 300 MHz and 3 GHz are used for mobile telephones, UHF TV, LANs, pagers, etc.
- Bluetooth uses 2.4 GHz
- Frequencies between 3 GHz and 30 GHz are used for microwave links, both terrestrial and satellite
- Higher frequencies used for wireless communications

Radio Waves, Microwaves, Infrared and Visible Light

- Infrared is used for some local area networks (IEEE 802.11) and for certain special purposes (e.g. remote controls)
- Infrared and visible light can be focused by lasers and used in systems based on free space optics
- Radio waves and infrared are normally broadcast
- For communications purposes, microwaves need to be focused
- The use of radio frequencies, including microwaves, is governed by international agreement and regulated by national governments

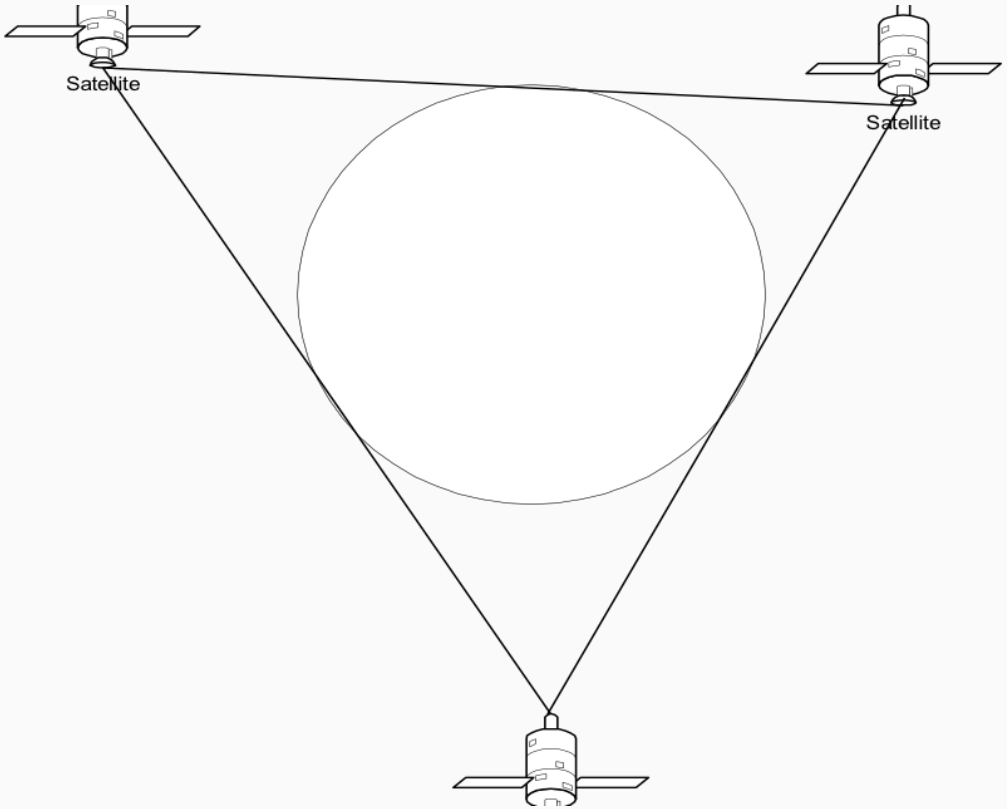
Terrestrial Microwaves

Microwaves travel in straight lines,
so communication is restricted to line of sight

Properties of Terrestrial Microwaves

- Repeaters are used for greater distances
- A single microwave channel can only operate in one direction
- Susceptible to interference and attenuation (depending on atmospheric conditions)
- High capital cost but not as high as laying fibre
- Possible to tap them but you need a lot of money and technology
- They are still used for voice telephony but have largely been replaced by fibre for data

Satellite Microwaves



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Properties of Satellite Links

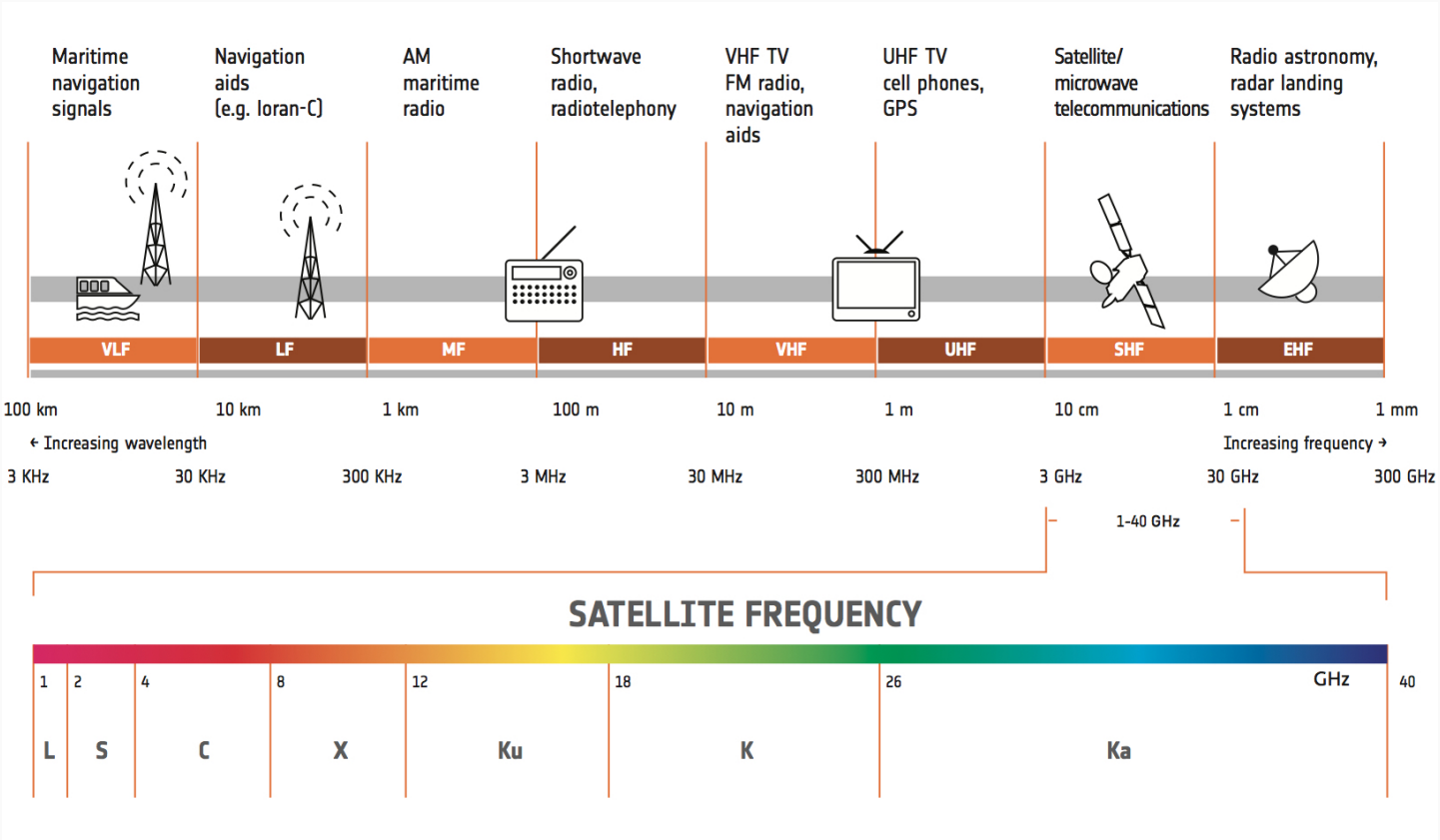
- Distances mean they are not tightly focused so possible to tap
- Used for satellite phones, for voice telephony and for data communications, but mostly for TV broadcasting
- Satellites are expensive but they provide enormous capacity, so using a bit of it is quite cheap

Properties of Satellite Links

- Geostationary satellites must orbit the earth above the equator at a height of 35 863 km[§]
- Propagation delays are therefore significant, which affects speech quality
- Now largely replaced by undersea fibre for voice but heavily used for data communications

[§]why? see here `https://en.wikipedia.org/wiki/Geostationary_orbit` or ask a physicist

Satellite Frequencies



Satellite transmission uses frequencies in the range of 1 GHz to 40 GHz

`http://www.esa.int/Our_Activities/Telecommunications_Integrated_Applications/Satellite_frequency_bands`

Wireless (Radio) Transmission

- Wireless LANs, cellular communication systems (mobile telephony, mobile computing), satellite phones
- Broadcast, so inherently insecure
- Subject to attenuation, distortion, dispersion and interference
- More or less line of sight at the very high frequencies (depends on atmospheric conditions)
- Lower frequencies are also used for radio/TV and other things
- Reflection leads to the problem of multiple paths

Infrared vs. Radio

Infrared

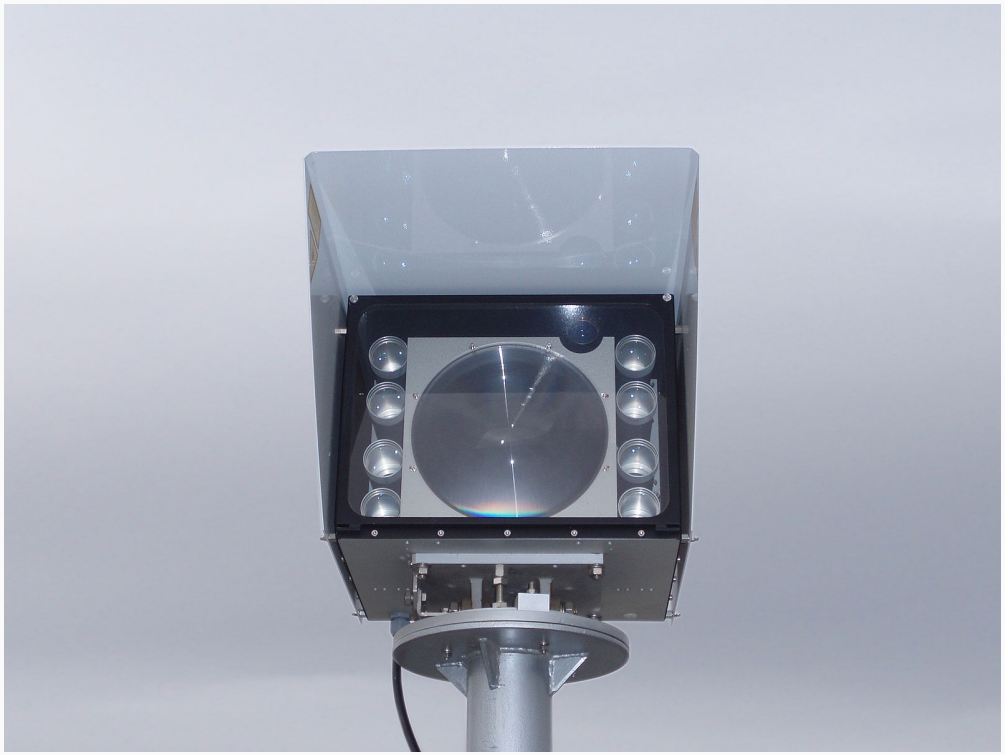
- Advantages:
  - simple and cheap
  - no licences needed for use of spectrum
  - shielding simple (just put something in the way)
  - no interference with or from electrical devices
  - reasonably secure (line of sight)
- Disavantages:
  - cannot penetrate walls
  - line of sight connection needed for good quality
  - low bandwidth

Infrared vs. Radio

Radio

- Advantages:
  - covers larger areas and can penetrate obstacles
  - line of sight generally unnecessary
  - transmission rates up to 54 Mbits/sec
- Disavantages:
  - shielding is difficult (radio waves can get through/round obstacles)
  - generates and is subject to interference
  - easy to tap (broadcast)
  - very limited range of frequencies available, with licences needed outside this range

Free Space Optics



Infrared, focused by a laser;

large Rx lens and a series of smaller Tx

Free Space Optics

- Line of sight required but can pass through windows
- Gives a channel capacity of up to 2.5 Gbps over distances up to about 3 km
- Used for ‘the last mile’ and for linking sections of local area networks
- No licensing problems

The important things to remember:

- Transmission media categories - learn the diagram!
- Know the overall factors affecting choice of medium:
  - cost, capacity, robustness, security
- Understand the properties of each type of medium

Next time...

Data Transmission

How we actually send the data